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Nutrition from the soil – The unexpected outcome of teaching experiments about photosynthesis.

Abstract

To consider students' conceptions has proven to be a crucial part in Science Education for all kinds of schools. The fundamental topic of photosynthesis, however, is often taught using historical experiments which do not take students' conceptions into account. In the following paper experiments by van-Helmont and Priestley about plant nutrition are discussed in regard of their efficacy. Based on the cognitive metaphor theory (Lakoff & Johnson, 1999) we analyse and interpret students' conceptions in order to gain a deeper understanding of their ways of thinking. In addition, a new theory and evidenced based experiment is developed that considers students' conceptions in an more appropriate way.

The status quo about photosynthesis

Photosynthesis is one of the basic processes of energy transformation in the biosphere and, therefore, the basis of almost all autotrophic and heterotrophic organisms. Photosynthesis does not simply produce the plants' biomass but also leads to crucial biological topics such as matter and energy flow within food webs. Despite its importance, studies have shown that assimilation processes are often understood in an every-day context. This leads to non-scientific conceptions. Studies reveal that when being asked if carbohydrates are produced by the process of photosynthesis, just 19% of the 13-year old students answered the question correctly (e.g. Barker & Carr, 1989). Anderson et al. (1990) found out that 98% of the interviewed students were convinced that plants receive their nutrition exclusively from their environment. As a consequence, these results lead to the following research questions: (1) What conceptions hinder or foster the understanding of photosynthesis? (2) In what way do experiments like van-Helmont and Priestly influence students' conceptions? (3) How do our new developed interventions trigger learning processes and conceptual changes?

Theory and Methods

But why is it so difficult to understand the process of photosynthesis? We approach the problem by re-thinking the topic from a different perspective: Based on the cognitive metaphor theory, every individual learns on the basis of personally acquired experiences (Lakoff & Johnson, 2008). Students convey these basic conceptions from their source area (nutrition and food) to target areas (photosynthesis) that cannot be experienced directly (Gropengießer, 1998). Consequently, not only do typical everyday conceptions evolve, some of them also differ tremendously from their scientific counterparts and, by that, compete with scientific ideas.

Looking at the students' language, it enables us to identify conceptions and to trace learning processes.

In our research, we focused on frequently used experiments by van-Helmont (plant nutrition) and Priestley (gas exchange). To identify students' conceptions and their learning processes, we set up teaching experiments video-taping three students each time (n=12 students, grade 9) (Steffe & D'Ambrosio, 1996). The original Science book applications showing the van-Helmont and Priestley experiment were given to the students. The proceeding 45min discussion was held to elicit the participants' conceptions and their explanations about the experiments' outcome. The gained data was compiled and analyzed by qualitative content analysis (Mayring, 2004). After transcribing and redacting the original recordings, utterances were context-oriented allocated before being matched into different categories (concepts). Thus, similar utterances from different students could be grouped and compared. As a next step, we looked for conceptual changes in order to find out whether the given interventions (van-Helmont, Priestley) had a positive or negative impact on learning processes.

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Results and Discussion

(1) Our results clearly show that the interviewed students have common conceptions about plant nutrition (n=11/12): e.g. nutrition is absorbed from the soil, oxygen is converted into carbon dioxide and light is transformed into matter. Confirming the findings of previous studies (e.g. Barker & Carr, 1989; Anderson, 1990) these results clearly indicate that students' conceptions hinder the understanding of photosynthesis.

(2) To change students' conceptions towards scientific conceptions historical-based experiments are frequently used. Even though such experiments are very common in schools, schoolbooks and teaching materials, our research shows an unexpected outcome: these interventions support and even consolidate students' non-scientific conceptions. The van-Helmont experiment confirms the hypothesis that it is not suitable to pass mental barriers such as the plants growth. All of the interviewed students either explained the plant's biomass increase with the absorption of water or were aware of the problem of mass conservation but had no appropriate answer to it. Seen from the cognitive metaphor theory, nutrition is seen as the mere absorption of "food". The Priestley intervention, however, focuses on gas exchange. As far as the impact on students' every-day conceptions is concerned, we found out that the intervention highly exacerbates the understanding of photosynthesis. Due to our analysis, Priestley reinforces the misconception of inverse respiration where students assume that plants directly transform carbon dioxide to oxygen. Animals on the other side absorb oxygen to produce carbon dioxide. Not only does the idea of a gaseous cycle appear, which reduces the process of photosynthesis to a mere gaseous input-output model, but also cell respiration is confined to animals and seen as the counter process of photosynthesis.

(3) It seems that crucial learning barriers in the field of photosynthesis cannot be passed by using historical experiments such as van-Helmont and Priestley. Due to these results, evidence-based interventions were derived to overtly address and question students' conceptions. A first approach aims at combining photosynthesis and cell respiration. Therefore, we developed an intervention to visualize carbon dioxide absorption (photosynthesis) and carbon dioxide release (cell respiration) by using the indicator bromine-thymol-blue. We decided on the commonly used specie *Elodea canadensis* as a laboratory plant. Whether the new developed intervention has significant impact on learning processes and has the suitability to change students' conceptions towards scientific conceptions has not been analyzed yet. Thus, the development of empirically evaluated interventions is strongly required.

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